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PARASITOLOGY AS AN INTERPRETIVE TOOL IN ARCHAEOLOGY

Karl J. Reinhard

Parasitological studies of archaeological sites can be used to interpret past behavior and living conditions. During the 1980s problem-oriented research into prehistoric- and historical-period parasitism developed and resulted in the field of archaeoparasitology. Archaeoparasitology attempts to integrate parasite data into archaeological theory and interpretation. Within the last decade, four major archaeoparasitological laboratories emerged. They developed interpretive frameworks that apply parasitological data to a remarkable variety of prehistoric behaviors. Parasite remains can be used to reconstruct aspects of diet, health, and other behaviors such as transhumance and trade. Finally, analysis of the distribution of parasite remains can be used to interpret aspects of site-formation processes.

Los estudios parasitológicos de sitios arqueológicos son utilizados para interpretar comportamientos y condiciones de vida en el pasado. El desarrollo de investigaciones orientadas a la problemática del parasitismo prehistórico e histórico durante la década de 1980 tuvo como resultado la creación de la arqueoparasitología. La arqueoparasitología intenta incorporar datos sobre parásitos a la teoría e interpretación arqueológicas. En la última década han surgido cuatro laboratorios parasitológicos principales. Estos han desarrollado marcos interpretativos que aplican datos parasitológicos a una notable variedad de comportamientos prehistóricos. Los restos de los parásitos se pueden utilizar para reconstruir aspectos relacionados con la dieta, la salud y otros comportamientos como la transhumancia y el comercio. Por último, el análisis de la distribución de los restos de los parásitos puede ser utilizado para interpretar aspectos de los procesos de formación de sitios arqueológicos.

Parasite remains from archaeological sites can address a remarkably broad range of questions regarding past behavior and environment. The application of parasitological data to archaeological questions has been a development of the last decade, when several distinct theoretical perspectives in archaeoparasitology (also paleoparasitology) developed in laboratories established in the 1980s. The emergence of these laboratories resulted in various applications of parasitological data to archaeological questions.

This paper summarizes the recent history of the field, describes current research centers and their theoretical perspectives, and illustrates specific applications to archaeology.

DEVELOPMENTS IN PARASITOLOGY IN THE 1980s

During the late 1970s and early 1980s, several laboratories specializing in archaeoparasitological research were established in the Americas and in Europe. The establishment of these occurred independently and consequently resulted in distinct theoretical orientations and applications as well as the innovation of analytical techniques (Reinhard et al. 1988). The four most important are those established by Ferreira, Araújo, and Confalonieri of the Fundação Oswaldo Cruz, Rio de Janeiro; Jones at the Environmental Archaeology Unit, University of York; Herrmann, Krügger, and Schultz at the Institut für Anthropologie, Universität Göttingen; and Ambler, Anderson, Hevly, and Reinhard at Northern Arizona University and now at the University of Nebraska–Lincoln. In addition there are other important researchers such as Fry, Allison, and Gerzten in the United States; Bonavia, Patrucco, and Tello in Peru; and Horne in Canada.

The concurrent, independent development of four major archaeoparasitological laboratories resulted in new applications of parasitological data to archaeological questions as discussed below.

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Each laboratory offered unique technical, methodological, and theoretical perspectives. Thus, it is of use to describe these laboratories before discussing their contributions to archaeological interpretation.

The Brazilian laboratory was composed of parasitologists who collaborated with archaeologists and was the most prolific laboratory in the 1980s (Ferreira et al. 1988). The research conducted by this group fell into the theoretical framework of biogeography; parasitological data were used to trace ancient distributions of South American parasites. This laboratory also developed techniques of differential diagnosis through refinement of diagnostic techniques (Araújo 1988; Araújo et al. 1980, 1982; Confalonieri et al. 1985, 1988; Ferreira et al. 1988). Latrine soils, coprolites, and mummy intestinal contents were studied. Currently, Brazilian research focuses on increasing the diagnostic precision of parasitological analysis, developing quantitative methods of parasite analysis for application to coprolites, and epidemiological study based on sixteenth-century documents. In addition, they have established a long-term research program in the Brazilian state of Piauí (Luiz Fernando Ferreira, personal communication 1989; Ulisses Confalonieri, personal communication 1990).

In Britain, archaeoparasitology developed from a long history of parasitological studies of medieval latrine deposits (Gooch 1983; Moore 1981; Pike 1967; Taylor 1955). The most recent theoretical developments have come from the incorporation of archaeoparasitological studies in "environmental archaeology" (Jones 1985). Thus, British research in the 1980s developed directly from archaeological concerns and was oriented toward the identification of the nature of archaeological deposits. In theory, parasite remains are seen as clues to depositional processes that create archaeological sites. When considered as indicators of site formation, parasite eggs are valuable indicators of the nature of archaeological soils. Specifically, they reflect human behavior and depositional processes that resulted in latrine deposits, middens, and living surfaces. Beyond this archaeological application, coprolites and mummies have been studied to assess the severity of medieval parasite infection (Jones 1986; Jones and Hall 1983; Jones et al. 1988) and in the identification of domestic horse use in Roman occupations (Jones et al. 1988). Recently, British researchers have begun the examination of South American mummies (Gordon Hill, personal communication 1990).

Very insightful archaeoparasitological research has been conducted in Germany (Herrmann 1986, 1987; Herrmann and Schultz 1987). A variety of depositional factors relevant to comparative parasite epidemiology were studied. German work focused on site-formation processes specific to the accumulation of parasite-egg assemblages in latrine deposits. Site-formation processes included differential egg production between parasite species, parasite burden (number of parasites inhabiting a human host), the number of hosts using a specific latrine, the effects of soil chemistry and decay organisms on differential preservation of helminth remains, and the role of human behavior in exposure to infective stages of different parasite species. These factors were viewed as having direct impact on the species diversity, representation, and egg concentration in excavated latrine samples. The German approach was holistic in its theoretical approach to archaeoparasitology and ultimately addressed comparative medieval helminth epidemiology in northern Europe. The German research, with its focus on comparative epidemiology, was clearly a development of paleopathology. However, the data also were interpreted within a cultural framework and therefore have a distinct anthropological orientation.

Archaeoparasitological research initiated at Northern Arizona University attempted to relate parasitism to human behavior (Hevly et al. 1979; Reinhard 1985a, 1988a, 1988b; Reinhard et al. 1985, 1987). This behavioral aspect of archaeoparasitology continues to be a focus of research conducted at the Archaeoparasitology Laboratory, University of Nebraska-Lincoln (Reinhard 1988a, 1990a). The theoretical framework involves concepts from both parasite ecology and human ecology and thus involves parasitologists and anthropologists. The role of human behavior in shaping parasitism (Reinhard 1985a, 1988a; Reinhard et al. 1985, 1987), the impact of environment on parasite diversity, and the influence of parasitism on prehistoric health (Hevly et al. 1979; Reinhard 1985b, 1985c, 1988a) are specific areas of interest. Dietary study, demographics, and archaeological reconstruction of behavior patterns are used to interpret parasitological finds in cultural context (Hevly et al. 1979; Reinhard 1985a, 1985b, 1985c, 1988a, 1990a; Reinhard et al. 1985, 1987). In

addition, there is emphasis on differential diagnosis of parasites (Reinhard 1985b) and the study of differential preservation of parasite remains (Reinhard and Clary 1986).

Research in the 1980s involved both paleontological (Araújo et al. 1982; Chame Dos Santos 1988; Reinhard 1990b) and archaeological remains (Horne 1985; Reinhard 1990a). Thus, there are two distinct trends in the study of ancient parasitism: paleontological study of ancient nonhumans and archaeological study of humans and domesticated animals. The goals of these separate fields already have been defined. Current paleontological studies address questions of changing parasite biogeography by comparing modern parasite distributions with ancient finds (Araújo et al. 1982). It is anticipated that continued studies will address questions such as speciation rates, migrations, and stability of host–parasite relations in changing environments (Araújo et al. 1982). In contrast, studies of archaeological parasitism focus on the cultural ecology of parasitism (Ferreira et al. 1988; Fry 1980; Reinhard 1988a, 1990a; Reinhard et al. 1987). Specifically, archaeoparasitology seeks to define the behaviors of archaeological peoples that intensified or limited parasitism of humans and domestic animals.

As these two subfields diverge, it is important to distinguish the two fields in terminology. Araújo et al. (1981) introduced the term “paleoparasitology” and defined it as an extension of paleopathology. Since then, the term has been applied to both archaeological and paleontological materials. For application to archaeological remains, the term “archaeoparasitology” was introduced by Reinhard (1990a). This term is descriptive for all parasitological remains excavated from archaeological contexts, both recent and remote, and is specific to remains derived from human activity. Because “paleo” refers to ancient times and conditions, I suggest that the term “paleoparasitology” be applied to studies of nonhuman, paleontological material.

DEFINITIONS AND CONCEPTS

In archaeological contexts, only the most durable parasite remains are likely to be found consistently. Helminths include the tapeworms (cestodes), flukes (trematodes), thorny-headed worms (acanthocephalans), and the roundworms (nematodes), which produce durable reproductive products (eggs and/or larvae). Rarely, adult nematodes are found in mummies (Allison et al. 1974), but usually the bodies of adult worms are too fragile to preserve. Thus, the primary sources of data are helminth eggs recovered from coprolites, mummies, and soils. Before proceeding to applications of archaeoparasitology to archaeology, it is necessary to present basic parasitological concepts and definitions.

Parasitism results from the interaction of at least two organisms (parasite and host) under environmental influences. The parasite gains nutrition and protection by living in or on another organism. The organism housing and nourishing the parasite is called a host. Both organisms usually are affected by aspects of the physical environment.

Hosts are classified according to what stage of the parasite life cycle occurs in or on them. Parasite sexual reproduction occurs in the definitive host. Asexual reproduction or larval development occurs in the intermediate host, of which there may be more than one in some parasite life cycles. Paratenic hosts harbor larval stages of parasites that do not undergo development. The parasite migrates to somatic tissue of the paratenic host, which may eventually be eaten by a definitive host. Accidental hosts are animals that are not typically infected with a given species of parasite. Zoonosis refers to human accidental infection with parasite species derived from another animal. When humans are the definitive, paratenic, or intermediate hosts of a parasite usually found in nonhumans, the infection is zoonotic. Because helminth eggs are the focus of study, parasites that use humans as definitive hosts are most emphasized. Only occasionally are cyst forms found, and these are found in special context, usually in mummies or in skeletal material.

Parasites can be classified into two major groups: obligate and facultative. Obligate parasites are those that must infect animals in order to complete their life cycles. Facultative parasites can either complete their life cycles as parasites or as free living animals.

Parasites often show a high degree of specificity. For example, pinworm (*Enterobius vermicularis*), the human whipworm (*Trichuris trichiura*), and the beef and pork tapeworms (*Taenia saginata* and

T. solium) can only complete their sexual reproduction in a human host. There are other parasites, however, that can exist in a wide range of hosts.

Several environmental factors affect parasite infection and thus the endemic areas of infection with many species are circumscribed. Most important of the environmental factors are temperature and moisture. In general, cold temperatures and dry conditions are less conducive to parasite transmission than warm temperatures and moist conditions. For this reason, a large proportion of human parasite species are limited to tropical and subtropical areas. Those parasites that utilize intermediate hosts are limited to those regions where the intermediate host occurs. Thus many species of fluke are limited to locations where snail intermediate hosts are present. Similarly, tapeworms are limited to areas where their intermediate hosts are found.

Most parasites have an extracorporal period in the life cycle during which eggs, larval stages, or both are exposed to the environment. Thus, infection is limited to circumscribed areas in which the environment is suitable for extracorporal development and survival. The limits of this area are increased or decreased by the hardiness of the extracorporal stages. For example *Ascaris lumbricoides* (giant round worm or maw worm) has a very durable egg that can survive in a variety of environments. Conversely, hookworm (*Ancylostoma duodenale* and *Necator americanus*) larvae hatch from the egg outside of the body, and the larvae are dependent on moist, warm conditions for survival. Consequently, *A. lumbricoides* is found in a variety of boreal, temperate, and subtropical habitats, whereas hookworms largely are limited to the tropics and subtropics.

With a few species, such an intimate relation is evolved between parasite and host that environmental factors have little effect on parasitism. For example, pinworm infections can occur without an extracorporal period. Therefore, archaeoparasitological evidence of pinworm can be found in virtually any ecological setting. Some parasites elude the limitations of environment by dispensing with extracorporal life-cycle stages. For example, *Trichinella spiralis*, the cause of trichinosis, usually has no extracorporal cycle. It is transmitted by carnivory (including scavenging) and the larvae, produced by reproductive adults in the intestine, migrate to somatic tissue.

A variety of nematode parasites evade the rigors of extracorporal survival by delaying reproduction until environmental conditions are suitable. Hypobiosis (suspended development) allows some species to survive in their host in larval form. Several parasites of veterinary importance utilize hypobiosis, for example *Haemonchus contortus* and *Ostertagia ostertagi* of ruminants. A few human parasites also may be hypobiotic such as *Ancylostoma duodenale* (hookworm), in which egg production coincides with the beginning of the rainy season to ensure that the eggs are laid in conditions suitable for larva survival.

False parasitism is a phenomenon that is characterized by the presence of parasite eggs in human feces of species not infectious to humans. This results from the consumption of an infected animal. The eggs in that animal's digestive tract are liberated in the human digestive tract and pass harmlessly through the system.

Reproductive products produced by parasites are varied in form and number. Some parasites, such as *T. spiralis*, lay larvae instead of eggs. Some, such as *Strongyloides stercoralis*, lay eggs that hatch in the intestine, and therefore larvae are defecated into the environment. The vast majority of the parasites encountered in archaeological contexts lay eggs. The number of eggs laid by an individual female varies from species to species. Some exhibit tremendous fecundity. *Ascaris lumbricoides* is reported by some researchers to lay 200,000 eggs per day. In comparison, *Trichostrongylus* (hairworm) lays less than 100 eggs per day, and *Strongyloides* lays about 50 eggs a day.

In some species, reproductive mechanisms minimize the chance of eggs being voided in feces. For example *E. vermicularis* lays its eggs on the perianal folds of its host. In the case of taeniid tapeworms, segments called proglottids break off from the worm and crawl out the anus. If the proglottid happens to be defecated, it can crawl out of the feces before desiccating and breaking.

One can see that these aspects of parasite fecundity and life cycle make one-to-one correlations of eggs to parasites impossible. For example, if a two-to-one ratio of *Ascaris* to *Trichostrongylus* eggs was found in a coprolite, this does not indicate that the host was parasitized by twice as many *Ascaris* than *Trichostrongylus*. The greater egg production of *Ascaris* results in the inequality of eggs. In actuality, considering how few eggs are laid by *Trichostrongylus* species, it would be far more

likely in this case that *Trichostrongylus* adults were more plentiful in the host intestine than *Ascaris*. Larvae are more susceptible to decay than are eggs, and consequently parasites that have a life cycle that includes the defecation of larvae probably will be underrepresented in the archaeological record. For example, if one finds more coprolites containing eggs of *Ascaris* than larvae of *Strongyloides* this does not necessarily represent a greater infection level with *Ascaris*. Differential preservation of eggs over larvae also could account for the difference.

Differential egg decomposition may have an important role in determining the ratios of parasite eggs found in latrine soil samples, although this does not seem to be a problem in coprolites or mummies. Both Herrmann (1986) and Reinhard et al. (1988) have noted fungal decomposition of *T. trichiura* (whipworm) eggs in latrines. Decomposition clearly was evident in whipworm eggs but not in *Ascaris* eggs. However, in certain historical-period contexts such as latrines from Colonial Williamsburg analyzed by the author, *Ascaris* eggs seem to exhibit greater decomposition than do *Trichuris* eggs. As yet, the details of differential decomposition are not understood. One would expect that the chitin egg shells of nematode parasites would preserve better than the shells of trematodes and cestodes that are made of a weaker material. However, differential preservation of these classes of eggs has not yet been noted in the archaeological record nor under experimental conditions (Reinhard 1988a).

In the study of archaeoparasitology, all of these factors must be considered, and all have potential application to the archaeological interpretation of parasite finds.

DATA SOURCES AND ANALYSIS TECHNIQUES

By 1985, cooperative efforts by researchers from the four major laboratories had resulted in the description of techniques for the recovery of parasite eggs (Reinhard et al. 1988). Also described are the remarkably varied contexts in which parasite remains are preserved (Ferreira et al. 1988; Jones et al. 1988; Reinhard 1990a; Reinhard et al. 1988). These include mummies, coprolites, latrine deposits, and fecal-contaminated trash middens and living surfaces.

The techniques of parasite recovery from mummies, coprolites, and latrine soils have been detailed elsewhere (Reinhard et al. 1986). Identification of helminth eggs is usually done with light microscopy. Examination of the egg size, dimension, and other morphological characters usually results in identification. However, when parasite larvae or adults are found, scanning-electron microscopy is of great diagnostic value (Allison et al. 1974; Araújo 1988). With some helminth taxa, the eggs are not identifiable to species with any microscopic technique. Immunological tests have been used to identify protozoan cysts (Faulkner 1991; Faulkner et al. 1989; Fouant 1981), and this approach may be applied to helminth eggs in the future.

Helminth parasite remains are found in a variety of environments. Mummies and coprolites usually provide excellent conditions for the preservation of helminth eggs and nematode adults and larvae. They have been the main source of parasitological data through the 1980s. However, helminth eggs can be found in a variety of habitats. Latrine soils or trash middens have been found to contain an abundance of parasite eggs. It is likely that middens and latrines will become the main source of parasitological data in the 1990s.

A critical interpretive problem is distinguishing true infections from false infections. This is especially true for extinct cultures whose food habits exposed them to parasites in prehistory that do not commonly occur in contemporaneous cultures with modern food practices. Usually, false infections consist of only a few accidentally ingested eggs. True infections result in the deposition of large numbers of eggs. Therefore, egg abundance is a key indicator of true infection.

Another interpretive problem results from the general morphological similarity of a few taxa of human parasites with nonhuman parasites. For example, the eggs of swine *Ascaris* and *Trichuris* are identical to those of humans. Therefore, in archaeological contexts in the Old World and the New World that date after permanent Euroamerican settlement it is impossible to distinguish some human parasite eggs from some swine parasite eggs. Circumstantial evidence such as the presence of eggs of other species that are specific to one host or the other can be used to infer a human origin. Similarly, the presence of archaeological latrine features can be used to infer a human origin,

providing those features were not used as receptacles for the entrails of butchered swine. Other interpretive problems will be mentioned below.

ARCHAEOLOGICAL APPLICATIONS

Diet

False parasitism can provide dietary information. In an analysis of an Eskimo mummy from St. Lawrence Island, Zimmerman (1980) discovered the eggs of the fluke *Cryptocotyle lingua*. This fluke uses fish as definitive hosts. The consumption of fish by humans results in the introduction of the eggs into the human digestive tract. Thus, in the case of the St. Lawrence Island mummy, the eggs provide evidence of fish consumption immediately prior to death (Zimmerman 1980; Zimmerman and Smith 1975).

With true parasitism, parasites that use intermediate hosts often show a high specificity for species of intermediate host. Thus, the finding of certain parasite eggs in an archaeological context provides direct evidence of the types of animals eaten. Because sexual stages of the parasites often are active for several months to several years, the eggs produced provide evidence of the consumption of certain animals even though direct evidence of those animals in archaeological context may be lacking.

Archaic coprolites recovered from the Pacific coast of Chile (Ferreira et al. 1984) and Peru (Callen and Cameron 1960; Patrucco et al. 1983) contained the eggs of *Diphyllbothrium pacificum*. This tapeworm uses fish as intermediate hosts, and diphyllbothriasis results from the consumption of fish that are uncooked or incompletely cured. Thus, the consistent identification of the eggs of this species in coprolites indicates that fish commonly were consumed along the western coast of South America. Diphyllbothriasis is a zoonosis, a disease of animals transmissible to humans. Seals are the normal definitive hosts for *D. pacificum*, but the consumption of poorly cooked fish by humans resulted in human infection. Current analysis of mummies by Reinhard and Barnum (1991) indicates that the infection was especially common among foragers who lived on the coast from 10,000 to 4,000 years ago and ate large quantities of fish. Analysis of horticultural mummies indicates that fish was later supplanted by tuber and fruit crops, and as a result diphyllbothriasis disappeared as a human infection.

Another group of tapeworms, the hymenolepidid worms, typically use rodents as definitive hosts and grain beetles as intermediate hosts. This cycle usually is associated with grain storage. Humans become accidental, definitive hosts for most hymenolepidid species by consuming grain beetles. Eggs of hymenolepidid worms have been found in coprolites and latrine soils from the prehistoric southwestern United States (Hevly et al. 1979; Reinhard 1985b; Reinhard et al. 1987). This indicates prehistoric grain stores were present and attracted rodents and beetles. It is probable that prehistoric peoples did not extract the beetles from the grain before preparation and consequently, infection resulted.

In terrestrial environments, the acanthocephalans (thorny-headed worms) use insects as intermediate hosts and a variety of mammals as definitive hosts. Acanthocephalan eggs have been found in human coprolites from the Great Basin and from the southwestern United States (Fry 1977; Fry and Hall 1969; Hall 1972, 1977; Moore et al. 1969). The species tentatively implicated is *Moniliformis clarki*, which uses camel crickets as intermediate hosts. Finding parasite eggs in human feces demonstrates that insects were consumed (Fry 1977). Hall (1972) notes that at least two acanthocephalan species are represented at Clyde's Cavern, Utah. He suggests that false parasitism is involved since people often consumed rodent definitive hosts. Whether or not these are true infections or false infections, the find of acanthocephalans directly reflects dietary habits, either the consumption of insects or the consumption of rodents.

The consumption of beef and/or pork is indicated by tapeworm eggs found in the Near East. The presence of taeniid tapeworm eggs in the intestine of an Egyptian mummy shows that poorly cooked beef or pork was eaten (Cockburn and Cockburn 1980).

In Germany, parasitism with *Fasciola hepatica* (sheep liver fluke) has been documented from medieval deposits (Herrmann 1986, 1987). Human infection results from the consumption of

unwashed greens collected from moist areas. Therefore, consumption of greens is indicated by the presence of the parasites. Animal husbandry also is implicated by the finds, since animal domestication often is associated with human infection.

Of all of the applications of parasite data to archaeology, dietary inferences are perhaps the least speculative. The consumption of a specific class of animal is indicated by the find of parasite eggs; fish tapeworm eggs indicate the consumption of fish; beef or pork tapeworm eggs reflect the consumption of beef or pork, etc. Thus, archaeoparasitology can have a strong role in the reconstruction of diet.

Transhumance and Trade

Unlike parasite species that often are limited geographically in range due to environmental parameters and extracorporal requirements, human populations can survive in a variety of ecological conditions. In residing seasonally in a specific habitat, a human population may pick up the parasite infections circumscribed in that habitat. When the human population moves to a second seasonal habitat, it carries with it the sexually reproducing parasites of the first habitat. Consequently, eggs will be passed in feces, and even though the parasites within those eggs cannot complete their life cycles in the second habitat, the eggs will become incorporated into the archaeological record. In archaeological interpretation, the eggs provide a marker of that first seasonal habitat.

This is exemplified by the finding of *T. trichiura* eggs in latrine soils at the prehistoric site of Elden Pueblo near Flagstaff, Arizona (Hevly et al. 1979; Reinhard et al. 1987). *T. trichiura* eggs require 21 days in warm, moist, densely shaded soils to become infective. Such conditions are not present today in the dry, cinder soils of the Flagstaff area. Ecological reconstruction of the region through palynology (Hevly et al. 1979) indicates that in prehistory the region was drier than today, making the possibility of *T. trichiura* life-cycle completion even more remote. Yet *T. trichiura* eggs were the most common eggs found in the latrines.

It is most probable that the inhabitants of Elden Pueblo were infected somewhere other than the Flagstaff area. The Verde River valley immediately south of the Flagstaff region would have provided the necessary conditions for *Trichuris* infection. Zooarchaeological evidence of turtle and fish species from the Verde River in the Elden Pueblo trash deposits indicates that some hunting and fishing was done along the Verde River (Hevly et al. 1979). It is very likely that seasonal movement from the Flagstaff region to the Verde Valley resulted in the infection of the human population. The eggs found in the latrines at Elden Pueblo are therefore probable markers of seasonal transhumance.

Transhumance or trade is represented by evidence of fish tapeworm *Diphyllobothrium pacificum* infection in Peru and Chile. The infection results from the consumption of incompletely cooked marine fish. Finds of the eggs of this species have been noted in coprolites and mummies from coastal areas. However, Araújo et al. (1983) reported finding *D. pacificum* eggs in 4 of 26 coprolites from the site of Tiliviche in northern Chile. Occupational levels at the site date from 4110 to 1950 B.C., and the site itself lies 40 km from the Pacific coast at an altitude of 950 m asl. These finds demonstrate that *D. pacificum* infection was not limited to the coast, but was present in inland, higher-elevation areas as well. This indicates that trade in fish reached inland or that inland peoples traveled to the coast to fish.

Caution must be employed when reconstructing trade or transhumance patterns based on parasitological data. Environmental change must also be considered as an alternative explanation for the presence of a parasite species prehistorically in an area unsuitable for its survival today. Thus, parasitological data should be interpreted in a framework that includes environmental reconstruction.

Environment

Because certain parasites are restricted to specific ecological conditions, the parasite evidence provides general data regarding the environments in which the human population lives. They also reflect ecological change between modern and prehistoric times.

For example, among modern Native Americans on the Colorado Plateau, *Enterobius vermicularis* is the only intestinal worm reported. In prehistory, eight intestinal parasites have been recorded, some of which are dependent on moist conditions for survival. One of these, *Strongyloides* spp., has been reported from Antelope House, Arizona (Reinhard 1985c), and Clyde's Cavern, Utah (Hall 1972). The presence of this parasite indicates that the prehistoric conditions were moister than at present, at least in the environments frequented by prehistoric pueblos. The evidence of rapid desiccation of coprolites indicates that environmental conditions of the latrines themselves were quite dry.

Hevly (1986) suggests that a combination of a generally moister environment and the use of irrigation resulted in conditions suitable for the survival of moisture-dependent parasites. Irrigation on a local level may have created an environment suitable for the survival of moisture-dependent parasites just as water-works projects in many parts of the modern world create conditions suitable for parasitic infection (Desowitz 1981).

Fluke eggs have been found in coprolites from the southwestern United States (Dunn and Watkins 1970; Moore et al. 1974). Flukes are, in general, dependent on moist conditions in order to infect snail intermediate hosts. The finding of fluke eggs in Lovelock Cave coprolites is not surprising considering the lacustrine environment of the cave (Dunn and Watkins 1970). The presence of fluke eggs in a human coprolite from Glen Canyon is unusual, for it indicates that the environments in which humans ranged in that arid region included mesic habitats (Moore et al. 1974).

Warm temperatures and moist conditions are prerequisites for hookworm infection. Hookworm eggs and adults have been found in coprolites and mummies in Brazil (Araújo et al. 1981; Ferreira et al. 1980, 1983, 1987) and Peru (Allison et al. 1974). These finds indicate that the peoples represented by these mummies and coprolites lived at least occasionally in moist, warm conditions.

When using parasite data for environmental reconstruction it is important to keep in mind that local environmental change resulting from agricultural practices as well as regional climatic change can expand the range of parasites. Thus, parasite data do not have the same interpretative value as pollen data. As opposed to pollen data that reflect regional changes, parasite data simply may reflect human modification of the environment on a local scale.

Health and Disease

The most obvious implication of parasitological finds relates to health and disease (Reinhard 1988a). Unfortunately, health inferences are often the most tenuous. The impact of parasites on community health is related to other factors such as the general nutritional status of the host population, other infectious organisms in the host population, immune status, and host-population size. Thus, the actual health threat of most parasites is difficult to evaluate. Also, many of the more common human parasites have adapted to human physiology and morphology such that little or no damage to the human host results from moderate infection.

Inferences regarding health are based not only on the pathogenicity of the specific parasite found, but also on its life cycle. When a life cycle is identified, then infection with other parasites having similar life cycles is implicated. For example, the finding of parasites that are transmitted through fecal contamination is evidence that the human-host population was at risk from other fecal-borne diseases such as amoebic dysentery that are not evident in the archaeological record. Thus, the find of *T. trichiura* and *A. lumbricoides*, both fecally transmitted, at Mt. Elden Pueblo, in numerous medieval latrines (Herrmann 1986), and in historical-period colonial American latrines (Reinhard 1990a) suggests that the inhabitants of these places were susceptible to infection with protozoa that also are associated with fecal contamination.

The most common of the human helminth parasites, pinworm (*Enterobius vermicularis*), is transmitted readily in conditions of poor personal hygiene and cramped living conditions. Similar conditions allow for the transmission of the louse *Pediculus humanus*. Therefore the find of pinworm signals suitable conditions for louse parasitism. Pinworm prevalence in coprolite samples from various sites also may reflect the general level of infectious disease associated with crowding and poor sanitation (Reinhard 1988b). However, pinworm itself is relatively harmless. Different prev-

alence of this parasite at different sites is an indicator of comparative hygiene rather than pathology (Araújo et al. 1985; Reinhard 1988a).

A few helminths cause disease outright. Hookworm, for example, causes severe anemia. The cranial lesions of *cribra orbitalia* and porotic hyperostosis may result from hookworm-induced anemia in certain areas (Steinbock 1976). Hookworm remains have been recovered from mummies and in coprolites from Peru and Brazil (Allison et al. 1974; Araújo et al. 1981; Ferreira et al. 1980, 1983). Probable hookworm remains have been found in Tennessee (Faulkner et al. 1989). It is possible that hookworm parasitism was a cause of anemia in areas where it is found archaeologically.

The fish tapeworm (*Diphyllbothrium*) is another helminth that is responsible for anemia, and some authors have implicated this parasite as a cause of porotic hyperostosis (Weir and Bonavia 1985). However, the anemia caused by diphyllbothriasis is less severe than that caused by hookworm. Therefore, it is unlikely that diphyllbothriasis resulted in cranial lesions. Evidence of diphyllbothriasis comes from Chile and Peru as noted above. It is possible that these parasites contributed to minor anemia on the coast of western South America, but it is unlikely that they were a major cause of anemia. In prehistoric Nubia, it is hypothesized that *Schistosoma* spp. caused prehistoric anemia (Hillson 1980). This inference has yet to be evaluated rigorously.

Hydatid cyst disease and trichinosis are two of the most debilitating diseases caused in humans by helminth parasites. Hydatid cyst disease is caused by species of the genus *Echinococcus*. Trichinosis is caused by *Trichinella spiralis*. Williams (1985) reports a case of hydatid cyst disease from a prehistoric skeleton in South Dakota, Ortner and Putschar (1983) describe a case from the Aleutian Islands, Weiss and Moller-Christensen (1971) describe a case from medieval Denmark, and Baud and Kramar (1991) report a case from medieval Switzerland. Only two percent of hydatid cysts cases show osseous involvement (Ortner and Putschar 1983). Therefore, the find of a single skeleton with cysts probably indicates that many others in the population were also infected. Zimmerman and Aufderheide (1984) report possible *Trichinella* cysts in muscle from an Inuit mummy from the north coast of Alaska. The pattern of pathology associated with this parasite (Schmidt and Roberts 1981) suggests that this population may have suffered from some debilitation and fatality due to trichinosis.

Other parasites that cause disease and are described and discussed in the archaeoparasitology literature from the New World include acanthocephalans in the Great Basin (Moore et al. 1969) and *Strongyloides stercoralis* at Antelope House, Arizona (Reinhard 1985b). Both of these parasites cause moderate to severe intestinal damage.

The absence of certain parasite data may indicate sanitation precautions that lessened the health impact of parasites. For example, Herrmann (1986) reports that although northern European medieval latrines contain eggs of several nematode (roundworm), trematode (flake), and cestode (tapeworm) species, there is a near absence of *Taenia* eggs, the genus of the pork and beef tapeworms. He suggests that meat inspectors of the time were especially efficient. Alternatively, the meat-preparation techniques employed in the area may have resulted in the killing of the tapeworm cysts by cooking. In either case, behavior mitigated parasitism with this species.

Archaeological Soil Analysis

One of the most direct applications of parasitological data to archaeology is the use of parasitological data in determining the nature of archaeological soils. This development has come primarily from examination of archaeological deposits in England (Jones 1985; Jones et al. 1988).

It originally was thought that parasite-egg preservation in latrines was dependent on moist soil conditions (Pike 1967). Recently Jones et al. (1988) have shown that a variety of soil types, some containing little or no obvious organic debris, contained parasite eggs. Jones (1985) used the concentration of eggs (number of parasite eggs per milliliter of soil) to distinguish fecal from nonfecal deposits in medieval and Bronze Age sites. This approach is useful even when the majority of organic remains are leached from the soil. An obvious application of this work is in the identification of soil strata conducive to dietary study. Since parasite eggs are deposited with feces, dietary remains in the form of seeds and pollen found in soils containing high numbers of eggs also are probably of dietary origin.

This work currently is applied to latrine analyses (Reinhard and Mrozowski, unpublished data; Reinhard et al. 1986) to determine which stratigraphic levels in latrines contain fecal debris. In the analysis of latrines from Newport, Rhode Island, Greenwich Village, New York, and Colonial Williamsburg, Virginia, the concentration of parasite eggs has a positive correlation with dietary pollen and seed concentration. Although this on-going research is still at a preliminary stage, it is apparent that parasite eggs can be used to determine which latrine levels are fecal and which levels are trash deposits. Once the fecal levels are isolated, they are submitted to dietary analysis through palynology and flotation.

Parasite data also can provide insights into the function of archaeological features. In recent analyses of soils from historical-period pit, well, and barrel features from Charleston, Philadelphia, and Colonial Williamsburg, parasite data were used to confirm or refute the hypothesized use of these features as latrines. For this purpose, the concentrations of parasite eggs per gram of soil were determined and then compared with Jones's (1985) standards of parasite concentrations associated with fecal remains.

Since parasite eggs in low frequency are typical of the "urban background fauna" (Jones 1985), the identification of parasite eggs in strata from urban contexts indicate that those strata probably are associated with human occupation. Thus, occupational horizons may be identifiable through soil analysis for parasite eggs.

Certainly not all sites are suitable for parasite analysis. Sites in environments not conducive to parasitism, or nonurban sites, probably will exhibit low concentrations of parasite eggs or no parasite eggs at all. Interpreting the nature of soils based on recovery of parasite eggs is probably best applied to urban sites.

Domestic Animals

Domestic-animal parasites are found occasionally in archaeological soils. The find of *Toxascaris* in feces from an Anasazi site is indicative of the presence of dogs (Reinhard 1990a). In my examination of latrine soils from the historic site of Lowell, Massachusetts, eggs of the horse pinworm *Oxyuris equi* were found that demonstrate that horses were present at the site. Jones et al. (1988) have found eggs of this species at a Roman fort dating to A.D. 80–90 in England, which demonstrates that horses were used at the fort. In terp soils from the Netherlands, a variety of domestic-animal parasites have been found, including *Toxocara canis* and *O. equi* indicating the presence of both horses and dogs (Pike 1967).

Parasites that use domestic animals as definitive hosts and humans as intermediate hosts are found in the archaeological record. For example, *Echinococcus* spp. commonly is found in dogs. The hydatid cysts found in human burials from North Dakota (Williams 1985) and the Aleutians (Ortner and Putschar 1983) suggest that dogs were associated with prehistoric populations. Humans become infected by consuming eggs passed by the dogs. Hydatid cysts, however, are not definitive indications of dog-human association since this parasite also infects wild canids.

Human-Parasite Ecology

Parasite ecology is affected strongly by human behaviors that include aspects of hygiene, sedentism, food preferences, food storage, and other practices. Archaeoparasitological research in the southwestern United States focuses on these aspects of human ecology and parasite ecology (Hevly et al. 1979; Reinhard 1988a, 1988b; Reinhard et al. 1987). Archaeoparasitological data are fit into an archaeological framework with the goal of demonstrating the impact of changing behavior concurrent with agriculture on the parasitology of Anasazi horticulturists in contrast with earlier Archaic hunter-gatherers. This approach has been very successful. A statistically significant increase in parasitism in agricultural peoples over Archaic hunter-gatherers has been demonstrated. Importantly, human-specific parasites were more common among agricultural peoples while zoonotic species dominated hunter-gatherer parasitism (Reinhard 1988a, 1988b; Reinhard et al. 1987). It is apparent that agricultural behavior left people at risk to fecal-borne parasites, parasites associated with grain

storage, and facultative parasites associated with moist soils. This research is important in elucidating the conditions that gave rise to human parasitism in the remote past.

Transpacific Contact?

In my opinion, some of the most provocative parasitological data come from hookworm (*Ancylostomidae*) and whipworm (*T. trichiura*) finds from South America (Araújo et al. 1988). Assuming that the only human migration route from Asia to the Americas was via Beringia, the find of hookworms and whipworms in prehistoric peoples is counterintuitive. Both taxa, but especially hookworms, require warm, moist conditions for the completion of their life cycles. Consequently, it is unlikely that whipworm, and impossible that hookworm, could survive in a population living under subarctic conditions. Because human hookworms and whipworm show a high degree of host specificity, it is unlikely that these parasites survived in New World indigenous animal populations to infect humans as people migrated southward into the subtropics and tropics of the Americas.

The finds have reopened an old parasitological debate concerning the origins of hookworm in the Americas (Araújo et al. 1988). Finds of the hookworm species *Ancylostoma duodenale* during the early 1900s in isolated South American native peoples led to speculation that this hookworm species was introduced into the New World in Precolumbian times (Darling 1921; Soper 1927). Manter (1967) suggested that if hookworm did indeed occur prehistorically, then it was likely to be introduced by transpacific contact. The discussion eventually abated. The find of hookworm in recent isolated populations was not considered to be irrefutable evidence of the prehistoric distribution of hookworm (Araújo et al. 1988). Many parasitologists believe that hookworm and whipworm were introduced into the New World by European expansion and slave trade with Africa.

Archaeoparasitological evidence of hookworm and whipworm infection have reopened the discussion (Araújo et al. 1988). Prehistoric hookworm infections have been described from mummies and coprolites from three sites in Brazil and one site in Peru. Probable hookworm eggs and larvae were found in a coprolite from Tennessee (Faulkner et al. 1989). Hookworm adult, larval, and egg stages have been described from prehistoric contexts and are irrefutable evidence of prehistoric hookworm infection. Whipworm eggs have been recovered from prehistoric sites in Arizona, Peru, and Brazil and also represent irrefutable evidence of human infection (Ferreira et al. 1988; Fouant 1981; Reinhard 1990a). Transpacific contact has been suggested as the route by which both hookworms (Araújo et al. 1988) and whipworms (Confalonieri 1988) were introduced into the prehistoric New World. It has been suggested that the most likely route was from southern Japan to coastal Ecuador. Thus, the find of human specific parasites that currently are limited to warm latitudes is viewed as circumstantial evidence of transpacific contact.

CONCLUSION

In the past most archaeoparasitological finds have been regarded by archaeologists and parasitologists as curiosities rather than as useful, scientific data. The maturation of archaeoparasitology during the last decade is beginning to change that view. This largely is due to the development of goal-oriented, theoretical perspectives in the 1980s and the involvement of anthropologically trained researchers in parasitological study. Now, these data can be applied to a wide range of archaeological questions.

The recovery potential for parasitological data is also broadening. In the past it was thought that parasitological data were only preserved in special contexts such as mummies or coprolites. The work with both historic and prehistoric archaeological soils demonstrates that parasite eggs are remarkably durable and nearly as resistant to decomposition as pollen grains. Therefore, the contexts from which one can potentially recover parasite eggs includes soil deposits with very little organic debris to humic latrine deposits rich in organic remains. In the future, there can be little doubt that refined techniques for the recovery of parasite remains will develop and that archaeological applications for parasitological study will continue to broaden. Therefore, as the field continues to mature, it undoubtedly will become a more useful tool for archaeological investigation.

REFERENCES CITED

- Allison, M. J., A. Pezzia, I. Hasigawa, and E. Gerszten
1974 A Case of Hookworm Infection in a Pre-Columbian American. *American Journal of Physical Anthropology* 41:103–106.
- Araújo, A. J. G.
1988 Dessecação experimental de fezes contendo ovos de ancilostomídeos. In *Paleoparasitologia no Brasil*, edited by L. F. Ferreira, A. Araújo, and U. E. C. Confalonieri, pp. 111–112. Programa de Educação Continuada/Escola Nacional de Saúde Pública, Rio de Janeiro.
- Araújo, A. J. G., U. E. C. Confalonieri, and L. F. Ferreira
1980 Oxyurid Infestations in Small Animals from 9,000 B.P. in Brazil. *Paleopathology Newsletter* 31:13–14. Detroit.
- 1982 Oxyurid (Nematoda) Eggs from Coprolites from Brazil. *Journal of Parasitology* 68:511–512.
- Araújo, A. J. G., L. F. Ferreira, and U. E. C. Confalonieri
1981 A Contribution to the Study of Helminth Findings in Archaeological Material in Brazil. *Revista Brasileira de Biologia* 41:873–881.
- Araújo, A. J. G., L. F. Ferreira, U. E. C. Confalonieri, and M. Chame
1988 Hookworms and the Peopling of the New World. *Cadernos de Saúde Pública, Rio de Janeiro* 2:226–233.
- Araújo, A. J. G., L. F. Ferreira, U. E. C. Confalonieri, and L. Nuñez
1983 Eggs of *Diphyllbothrium pacificum* in Pre-Columbian Human Coprolites. *Paleopathology Newsletter* 41:11–113. Detroit.
- Araújo, A. J. G., L. F. Ferreira, U. E. C. Confalonieri, L. Nuñez, and B. M. Ribeiro Filho
1985 The Finding of *Enterobius vermicularis* Eggs in Pre-Columbian Human Coprolites. *Memorias do Instituto Oswaldo Cruz* 80:141–143. Rio de Janeiro.
- Baud, C. A., and C. Kramar
1991 Soft Tissue Calcifications in Paleopathology. In *Human Paleopathology: Current Syntheses and Future Options*, edited by D. J. Ortner and A. C. Aufderheide, pp. 87–89. Smithsonian Institution Press, Washington, D.C.
- Callen, E. O., and T. W. M. Cameron
1960 A Prehistoric Diet Revealed in Coprolites. *New Scientist* 8:35–40.
- Chame Dos Santos, M.
1988 *Estudio comparativo das fezes e coprólitos nao humanos da regioa arqueológica de sao Raimundo Nonato Sudeste do Piauí*. Unpublished Master's thesis, Department of Biology, Universidade Federal do Rio de Janeiro.
- Cockburn, A., and E. Cockburn
1980 *Mummies, Disease, and Ancient Cultures*. Cambridge University Press, London.
- Confalonieri, U.
1988 Paleoepidemiologia de *T. trichiura* na America. In *Paleoparasitologia no Brasil*, edited by L. F. Ferreira, A. Araújo, and U. Confalonieri, pp. 120–137. Programa de Educação Continuada/Escola Nacional de Saúde Pública, Rio de Janeiro.
- Confalonieri, U. E. C., A. J. G. Araújo, and L. F. Ferreira
1988 The Use of a Statistical Test for the Identification of Helminth Eggs in Coprolites. *Paleopathology Newsletter* 62:7–8. Detroit.
- Confalonieri, U. E. C., B. M. Ribeiro Filho, L. F. Ferreira, and A. G. Araújo
1985 The Experimental Approach to Paleoparasitology: Desiccation of *Trichuris trichiura* Eggs. *Paleopathology Newsletter* 51:9–11. Detroit.
- Darling, S. T.
1921 Observations on the Geographical and Ethnological Distribution of Hookworms. *Parasitology* 12:217–233.
- Desowitz, R. S.
1981 *New Guinea Tapeworms and Jewish Grandmothers: Tales of Parasites and People*. Norton, New York.
- Dunn, F. L., and R. Watkins
1970 Parasitological Examination of Prehistoric Human Coprolites from Lovelock Cave, Nevada. *Contributions of the University of California Archaeological Research Facility* 10:176–185. Berkeley.
- Faulkner, C. T.
1991 Prehistoric Diet and Parasitic Infection in Tennessee: Evidence from the Analysis of Desiccated Human Paleofeces. *American Antiquity* 56:687–700.
- Faulkner, C. T., S. Patton, and S. S. Johnson
1989 Prehistoric Parasitism in Tennessee: Evidence from the Analysis of Desiccated Fecal Material Collected from Big Bone Cave, Van Buren County, Tennessee. *Journal of Parasitology* 75:461–463.
- Ferreira, L. F., A. J. G. Araújo, and U. E. C. Confalonieri
1980 The Finding of Eggs and Larvae of Parasitic Helminths in Archaeological Material from Unai, Minas Gerais, Brazil. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 74:798–800. London.

- 1983 The Finding of Helminth Eggs in a Brazilian Mummy. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 77:65–67. London.
- 1988 *Paleoparasitologia no Brasil*. Programa de Educacao Continuada/Escola Nacional de Saude Publica, Rio de Janeiro.
- Ferreira, L. F., A. J. G. Araújo, U. E. C. Confalonieri, and L. Nuñez
- 1984 The Finding of *Diphyllobothrium* in Human Coprolites (4,000–1,950 B.C.) from Northern Chile. *Memorias do Instituto Oswaldo Cruz* 79:175–180. Rio de Janeiro.
- Ferreira, L. F., A. J. G. Araújo, U. E. C. Confalonieri, M. Chame, and B. Ribiero Filho
- 1987 Encontro de ovos de ancilostomídeos em coprolitos humanos datados de $7,230 \pm 80$ anos, no estado Piauí, Brasil. X Congresso da Sociedade Brasileira de Parasitologia Salvador, Bahia.
- Fouant, M. M.
- 1981 *Intestinal Parasitic Disease Among Pre-Columbian Indians*. Unpublished Master's thesis, Department of Pathology, Medical College of Virginia, Richmond.
- Fry, G. F.
- 1977 *Analysis of Prehistoric Coprolites from Utah*. Anthropological Papers No. 97. University of Utah, Salt Lake City.
- 1980 Prehistoric Diet and Parasites in the Desert West of North America. In *Early Native Americans*, edited by D. L. Browman, pp. 325–339. Mouton, The Hague.
- Fry, G. F., and H. J. Hall
- 1969 Parasitological Examination of Human Coprolites from Utah. *Proceedings of the Utah Academy of Science, Arts and Letters* 36:102–105. Salt Lake City.
- Gooch, P. S.
- 1983 Helminth Parasites. In *Disease in Ancient Man*, edited by G. D. Hart, pp. 205–211. Clarke Irwin, Toronto.
- Hall, H. J.
- 1972 *Diet and Disease at Clyde's Cavern, Utah*. Unpublished Master's thesis, Department of Anthropology, University of Utah, Salt Lake City.
- 1977 A Paleoscatological Study of Diet and Disease at Dirty Shame Rockshelter, Southwest Oregon. *Tebiwa* 8:1–15.
- Herrmann, B.
- 1986 Parasitologische Untersuchung mittelalterlicher Kloaken. In *Mensch und Umwelt im Mittelalter*, edited by B. Herrmann, pp. 161–169. Deutsche Verlags-Anstalt, Stuttgart.
- 1987 Parasitologisch-Epidemiologische Auswertungen mittelalterlicher Kloaken. *Zeitschrift für Archäologie des Mittelalters* 13:131–161. Köln.
- Herrmann, B., and U. Schultz
- 1987 Parasitologische Untersuchungen eines Spätmittelalterlich-frühneuzeitlichen Koakeninhaltes aus der Fronerei auf dem Schranken in Lübeck. *Lübecker Schriften zur Archäologie und Kulturgeschichte* 12:167–172. Lübeck.
- Hevly, R. H.
- 1986 Paleoeological Changes Relevant to Prehistoric Helminthiasis. Paper presented at the 13th Annual Meeting of the Paleopathology Association, Albuquerque.
- Hevly, R. H., R. E. Kelly, G. A. Anderson, and S. J. Olsen
- 1979 Comparative Effects of Climate Change, Cultural Impact, and Volcanism in the Paleoeology of Flagstaff, Arizona, A.D. 900–1300. In *Volcanic Activity and Human History*, edited by P. Sheets and D. Grayson, pp. 487–523. Academic Press, New York.
- Hillson, S. W.
- 1980 Chronic Anemias in the Nile Valley. *MASCA Journal* 1:172.
- Horne, P. D.
- 1985 A Review of the Evidence of Human Endoparasitism in the Pre-Columbian New World Through the Study of Coprolites. *Journal of Archaeological Science* 12:299–310.
- Jones, A. K. G.
- 1985 Trichurid Ova in Archaeological Deposits: Their Value as Indicators of Ancient Feces. In *Paleobiological Investigations: Research Design, Methods and Data Analysis*, edited by N. J. R. Fieller, D. D. Gilbertson, and N. G. A. Ralph, pp. 105–114. BAR International Series 266. British Archaeological Reports, Oxford.
- 1986 Parasitological Examination of Lindow Man. In *Lindow Man: The Body in the Bog*, edited by I. M. Stead, J. B. Bourke, D. Williams, and D. Brothwell, pp. 136–139. British Museum Publications, London.
- Jones, A. K. G., and A. R. Hall
- 1983 A Coprolite from 6–8 Pavement. In *Environment and Living Conditions at Two Anglo-Scandinavian Sites*, edited by A. R. Hall, H. K. Kenward, D. Williams, and J. R. A. Greig, pp. 225–229. Council for British Archaeology, York.
- Jones, A. K. G., A. R. Hutchinson, and C. Nicholson
- 1988 The Worms of Roman Horses and Other Finds of Intestinal Parasite Eggs from Unpromising Deposits. *Antiquity* 62:225–229.

- Manter, H. W.
1967 Some Aspects of the Geographical Distribution of Parasites. *Journal of Parasitology* 53:1-9.
- Moore, J. G., G. F. Fry, and E. Englert
1969 Thorny-Headed Worm Infection in North American Prehistoric Man. *Science* 163:1324-1325.
- Moore, J. G., A. W. Grundman, H. J. Hall, and G. F. Fry
1974 Human Fluke Infection in Glen Canyon at AD 1250. *American Journal of Physical Anthropology* 41: 115-118.
- Moore, P. D.
1981 Life Seen from a Medieval Latrine. *Nature* 294:614.
- Ortner, D. J., and W. G. J. Putschar
1983 *Identification of Pathological Conditions in Human Skeletal Remains*. Smithsonian Institution Press, Washington, D.C.
- Ortner, D. J., L. Tello, and D. Bonavia
1988 Parasitological Finds of Coprolites of Pre-Hispanic Peruvian Populations. *Current Anthropology* 24: 393-394.
- Pike, A. W.
1967 The Recovery of Parasite Eggs from Ancient Cesspit and Latrine Deposits: An Approach to the Study of Early Parasite Infections. In *Disease in Antiquity*, edited by D. Brothwell and A. T. Sandison, pp. 184-188. Thomas, Springfield, Illinois.
- Reinhard, K. J.
1985a *Recovery of Helminths from Prehistoric Feces: The Cultural Ecology of Ancient Parasitism*. Unpublished Master's thesis, Department of Biological Sciences, Northern Arizona University, Flagstaff.
1985b Parasitism at Antelope House, a Puebloan Village in Canyon de Chelly, Arizona. In *Health and Disease in the Prehistoric Southwest*, edited by C. F. Merbs and R. J. Miller, pp. 220-223. Anthropological Research Papers No. 34. Arizona State University, Tempe.
1985c *Strongyloides stercoralis* in the Prehistoric Southwest. In *Health and Disease in the Prehistoric Southwest*, edited by C. F. Merbs and R. J. Miller, pp. 234-242. Anthropological Research Papers No. 34. Arizona State University, Tempe.
1988a Cultural Ecology of Prehistoric Parasitism on the Colorado Plateau as Evidenced by Coprology. *American Journal of Physical Anthropology* 77:355-366.
1988b *Diet, Parasitism, and Anemia in the Prehistoric Southwest*. Unpublished Ph.D. dissertation, Department of Anthropology, Texas A&M University, College Station.
1990a Archaeoparasitology in North America. *American Journal of Physical Anthropology* 82:145-163.
1990b Paleoparasitology of Alligators as Evidenced by Helminth Eggs from Coprolites Recovered from a Florida Bog. Paper presented at the 50th Annual Meeting of the Society of Vertebrate Paleontology, Lawrence, Kansas.
- Reinhard, K. J., and S. V. Barnum
1991 Ancient Parasitology of Coastal Peru. Paper presented at the 90th Annual Meeting of the American Anthropological Association, Chicago.
- Reinhard, K. J., and K. H. Clary
1986 Parasite Analysis of Prehistoric Coprolites from Chaco Canyon, New Mexico. In *A Biocultural Approach to Human Burials from Chaco Canyon, New Mexico*, edited by N. J. Akins, pp. 214-222. Reports of the Chaco Center No. 9. National Park Service, Santa Fe.
- Reinhard, K. J., J. R. Ambler, and M. McGuffie
1985 Diet and Parasitism at Dust Devil Cave. *American Antiquity* 50:819-824.
- Reinhard, K. J., R. H. Hevly, and G. A. Anderson
1987 Helminth Remains from Prehistoric Indian Coprolites on the Colorado Plateau. *Journal of Parasitology* 73:630-639.
- Reinhard, K. J., S. A. Mrozowski, and K. A. Orloski
1986 Privies, Pollen, Parasites and Seeds, a Biological Nexus in Historic Archaeology. *MASCA Journal* 4: 31-36.
- Reinhard, K. J., U. E. Confalonieri, B. Herrmann, L. F. Ferreira, and A. J. G. Araújo
1988 Recovery of Parasite Eggs from Coprolites and Latrines: Aspects of Paleoparasitological Technique. *Homo* 37:217-239.
- Schmidt G. D., and L. S. Roberts
1981 *Foundations of Parasitology*. Mosby, New York.
- Soper, F. L.
1927 The Report of Nearly Pure *Ancylostoma duodenale* in Native South American Indians and a Discussion of Its Ethnological Significance. *American Journal of Hygiene* 7:174-184.
- Steinbock, R. T.
1976 *Paleopathological Diagnosis and Interpretation: Bone Diseases in Ancient Human Populations*. Thomas, Springfield, Illinois.
- Taylor, E. L.
1955 Parasitic Helminths in Mediaeval Remains. *Veterinary Record* 67:216-218.

- Weir, G. H., and D. Bonavia
1985 Coprolitos y dieta del Precerámico Tardío de la costa Peruana. *Bulletin of the French Institute of Andean Studies* 14:85–140.
- Weiss, D. L., and V. Moller-Christensen
1971 Leprosy, Echinococcosis and Amulets: A Study of a Medieval Danish Inhumation. *Medical History* 15:260–267.
- Williams, J. A.
1985 Evidence of Hydatid Cyst Disease in a Plains Woodland Burial. *Plains Anthropologist* 30:25–28.
- Zimmerman, M. R.
1980 Aleutian and Alaskan Mummies. In *Mummies, Disease, and Ancient Cultures*, edited by A. Cockburn and E. Cockburn, pp. 118–134. Cambridge University Press, London.
- Zimmerman, M. R., and A. Aufderheide
1984 The Frozen Family of Utqiugvik: The Autopsy Findings. *Arctic Anthropology* 21:53–64.
- Zimmerman, M. R., and G. S. Smith
1975 A Probable Case of Accidental Inhumation of 1,600 Years Ago. *Bulletin of the New York Academy of Medicine* 51:828–837. New York.

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